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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/671,126	09/25/2003	Oleg Logvinov	102362-036 US	7294

7590 04/13/2007

Mr. James Reeder
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EXAMINER	
MUI, GARY	
ART UNIT	**PAPER NUMBER**
2616	

SHORTENED STATUTORY PERIOD OF RESPONSE	MAIL DATE	DELIVERY MODE
3 MONTHS	04/13/2007	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

If NO period for reply is specified above, the maximum statutory period will apply and will expire 6 MONTHS from the mailing date of this communication.

Office Action Summary	Application No.	Applicant(s)	
	10/671,126	LOGVINOV ET AL.	
	Examiner	Art Unit	
	Gary Mui	2616	

-- *The MAILING DATE of this communication appears on the cover sheet with the correspondence address* --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on 25 September 2003.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) 1-23 is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) 1-23 is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on 25 September 2003 is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)

3) ☒ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____.

4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

5) ☐ Notice of Informal Patent Application

6) ☐ Other: _____.

DETAILED ACTION

Claim Objections

1. Claims 1 and 13 – 22 are objected to under 37 CFR 1.75 because of the following informalities:

For claim 1 line 3, the occurrence of "at at" seems to be a typo, it is suggested to the applicant to remove one "at". Similar problem exists for claim 13 line 4.

Claims 14 – 22 are objected to because they depend on an objected claim.

Appropriate correction is required.

Claim Rejections - 35 USC § 102

2. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (e) the invention was described in (1) an application for patent, published under section 122(b), by another filed in the United States before the invention by the applicant for patent or (2) a patent granted on an application for patent by another filed in the United States before the invention by the applicant for patent, except that an international application filed under the treaty defined in section 351(a) shall have the effects for purposes of this subsection of an application filed in the United States only if the international application designated the United States and was published under Article 21(2) of such treaty in the English language.

3. Claims 1 and 23 are rejected under 35 U.S.C. 102(e) as being anticipated by Litwin, Jr. et al. (US 6,834,091 B2).

For claim 1, Litwin, Jr. et al. teaches that at least one of the PLC nodes, establishing a timing controlled PLC data signal communication frame, wherein the frame includes synchronization data and has a predetermination duration (see column 1 lines 60 – 67); transmitting the frame onto the PLC system at predetermined intervals (see column 2 lines 1 – 5); and transmitting PLC signals among the PLC nodes in accordance with the timing frame (see column 2 lines 5

– 7, the master device is sending synchronization information to the plurality of devices and then the devices transmit during its time slot).

Claim Rejections - 35 USC § 103

4. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

5. The factual inquiries set forth in *Graham* v. *John Deere Co.*, 383 U.S. 1, 148 USPQ 459 (1966), that are applied for establishing a background for determining obviousness under 35 U.S.C. 103(a) are summarized as follows:

1. Determining the scope and contents of the prior art.
2. Ascertaining the differences between the prior art and the claims at issue.
3. Resolving the level of ordinary skill in the pertinent art.
4. Considering objective evidence present in the application indicating obviousness or nonobviousness.

6. . This application currently names joint inventors. In considering patentability of the claims under 35 U.S.C. 103(a), the examiner presumes that the subject matter of the various claims was commonly owned at the time any inventions covered therein were made absent any evidence to the contrary. Applicant is advised of the obligation under 37 CFR 1.56 to point out the inventor and invention dates of each claim that was not commonly owned at the time a later invention was made in order for the examiner to consider the applicability of 35 U.S.C. 103(c) and potential 35 U.S.C. 102(e), (f) or (g) prior art under 35 U.S.C. 103(a).

7. Claims 2 – 7, 8 – 18, and 20 – 23 are rejected under 35 U.S.C. 103(a) as being unpatentable over Litwin, Jr. et al. in view of Schobinger et al. (Non Patent Literature/A Low-cost Point-to-Multi-point Access System based on OFDM Transmission).

For claim 2, Litwin, Jr. et al. teaches establishing a timing controlled PLC data signal communication frame having a predetermined duration (see column 1 lines 60 – 67); selectively allocating a first portion of the duration of the timing frame to the downstream time slot and a second portion of the duration to the at least one upstream time slot; transmitting the frame onto the PLC system at predetermined intervals (see column 2 lines 1 – 5); and transmitting PLC signals between the head-end and at least one of the remotes in accordance with the timing frame (see column 2 lines 5 – 7, the master device is sending synchronization information to the plurality of devices and then the devices transmit during its time slot). Litwin, Jr. et al. fails to teach the timing frame includes a downstream time slot assigned for transmission of PLC data signals form the head-end to at least of one of the remotes and at least one upstream time slot assigned for transmission of PLC data signals from at least one of the remotes to the head-end. Schobinger et al. from the same field of endeavor teaches granting upstream-transmission for several slaves can be done in one slot transmitting slave address and corresponding upstream-slot numbers (see page v - 418 column 2 lines 42 – 44). Therefore, it would have been obvious to one of ordinary skill in the art at the time of the invention was made to have the timing frame of Litwin, Jr. et al. to include time slot assignment information as taught by Schobinger et al. The motivation for doing this is to have an efficient communication system by avoiding collisions.

For claim 13, Litwin, Jr. et al. teaches a head-end PLC transceiver (see figure 1 box 14) coupled to a plurality of remote PLC transceivers (see figure 1 boxes 16 and 18) over a PLC network wherein the head-end transmit downstream data signals for reception at least one of the remotes and at least one of the remotes transmits upstream data signals for reception at the head-end in accordance with a timing controlled PLC data signal communications frame having a predetermined duration and wherein the head-end transmits the frame onto the PLC system at predetermined intervals (see column 2 lines 1 – 7). Litwin, Jr. et al. fails to teach the timing frame includes a downstream time slot assigned for the downstream data signals and at least one upstream time slot assigned for the upstream data signals, wherein the downstream time slot occupies a first portion of the duration of the timing frame and the upstream time slot occupies a second portion of the duration of the timing frame and wherein the lengths of the first and second portions are selectable. Schobinger et al. from the same field of endeavor teaches granting upstream-transmission for several slaves and be done in one slot transmitting address and corresponding upstream-slots numbers (see page v - 418 column 2 lines 42 – 44). Therefore, it would have been obvious to one of ordinary skill in the art at the time of the invention was made to have timing frame of Litwin, Jr. et al. to include time slot assignment information as taught by Schobinger et al. The motivation for ding this is to have an efficient communication system by avoiding collisions.

For claims 3, 4, 14, and 15, Litwin, Jr. et al. teaches the PLC system is a frequency division multiplexing system and that the frequency division multiplexed system is an orthogonal frequency division multiplexed ("OFDM") system (see column 4 lines 17 – 18).

For claims 5 and 16, Litwin, Jr. et al. fails to teach the head-end transmits an OFDM PLC signal simultaneously to a plurality of the remotes, wherein the OFDM signal contains an OFDM symbol for each of the remotes, each of the OFDM symbols contain at least one predetermined tone and the at least one tone is different for each of the remotes. Schobinger et al. teaches with orthogonal sub-carriers the required signal processing in transmitter and receiver can be realized wit a discrete Fourier transform (IDFT/DFT) (see page v - 418 column 1 lines 4 – 6). Schobinger et al. also teaches registered slaves are polled in a periodical scheme whether they have a transmission request and to scan their status. This requires one slot taking the time of one OFDM-block, as different slaves can't share one OFDM-block (see page v - 418 column 2 lines 37 – 41). Therefore, it would have been obvious to one of ordinary skill in the art at the time of the invention was made to transmit OFDM signals simultaneously and each remote have it own tone as taught by Schobinger et al. into the PLC system as taught by Litwin, Jr. et al. The motivation for doing this is to provide for a higher throughput and a more efficient transmission.

For claims 6 and 17, Litwin, Jr. et al. fails to teach the first portion is not equal to the second portion. Schobinger et al. from the same field of endeavor teaches asymmetric data-rate between up-link and down-link should be possible (see page v - 418 lines 3 – 4). Therefore, it would have been obvious to one of ordinary skill in the art at the time of the invention was made to have an asynchronous transmission as taught by Schobinger et al. into the PLC system as taught by Litwin, Jr. et al. The motivation for doing this is to have a higher throughput communication system.

For claims 7 and 18, Litwin, Jr. et al. fails to teach the selectively allocation the duration of the timing frame includes dynamically changing the size of at least one of the first and second potions. Schobinger et al. from the same field of endeavor teaches options to use reduced data-rates communication with slaves having a very bad channel. Therefore, it would have been obvious to one of ordinary skill in the art at the time of the invention was made to adjustable sizes as taught by Schobinger et al. into the PLC system of Litwin, Jr. et al. The motivation for doing this is to have a more efficient transmission system by allowing for the saving bandwidth.

For claims 9 – 11 and 20 – 22, Litwin, Jr. et al. fails to teach transmitting from the head-end a downstream orthogonal frequency division multiplexed ("OFDM") data signal having a first number of carriers and a first symbol length, transmitting from at least one of the remotes an upstream OFDM signal having a second number of carriers and a second symbol length, wherein the first number of carriers is greater than the second number of carriers and the first symbol length is longer than the second symbol length; a plurality of the remotes transmits OFDM data signals and wherein the first symbol lengths exceeds the sum of the second symbol lengths for the OFDM signals transmitted by the respective plurality of the remotes; and wherein the head-end can only decode an OFDM data signal having a number of carriers and a symbol length substantially different from the first number of carriers and the first symbol length, respectively, and wherein at least one of the remotes can only decode an OFDM data signal having a number of carriers and a symbol length substantially different from the second number of carriers and the second symbol length, respectively. Schobinger et al. also fails to explicitly teach it but it is inherent in Schobinger OFDM system to have

multiple carriers and symbol lengths. It is also inherent that in a point-to-multipoint system that there will be more carries on one end then the other and the sum of the symbol lengths be greater; also when there is more then the head-end or remote can only decode when the number or carriers and symbol lengths are different. Therefore, it would have been obvious to one of ordinary skill in the art at the time of the invention was made to have different symbol lengths. The motivation for doing this is allow for a larger and effective communication system.

For claim 12, Litwin, Jr. et al. teaches the timing frame is a time division multiplexed PLC data signal communication frame (see column 3 lines 53 – 55).

For claim 23, Litwin, Jr. et al. teaches a PLC transmitter module for generating and transmitting downstream PLC signals (see figure 1 box 20 of box 14) to at least one of at least one of a plurality of remote PLC transceivers (see figure 1 boxes 16 and 18) coupled to the head-end over a PLC network; a PLC receiver module for receiving upstream PLC signals transmitted form at least one of the remotes (see figure 1 box20 of box 14); and the PLC transmitter module computes a timing controlled PLC data signal compunction frame having a predetermined duration (see column 1 lines 60 – 67). Litwin, Jr. et al. fails to teach the timing frame includes a downstream time slot assigned for transmission of PLC data signals from the head-end to at least one of the remotes and at least one upstream time slot assigned for transmission of PLC data signals form at least one of the remotes to the head-end, wherein a first portion of the duration of the timing frame is allocated to the downstream time slot and a second portion of the duration is allocated to the at least one upstream time slot. Schobinger et al. from the same field of endeavor teaches granting upstream-transmission for several

slaves and be done in one slot transmitting address and corresponding upstream-slots numbers (see page v - 418 column 2 lines 42 – 44). Therefore, it would have been obvious to one of ordinary skill in the art at the time of the invention was made to have timing frame of Litwin, Jr. et al. to include time slot assignment information as taught by Schobinger et al. The motivation for ding this is to have an efficient communication system by avoiding collisions.

Claim Rejections - 35 USC § 103

8. Claims 8 and 19 are rejected under 35 U.S.C. 103(a) as being unpatentable over Litwin, Jr. et al. and Schobinger et al. as applied to claims 2 and 13 above, and further in view of Balhut (US 6,778,550 B1).

For claims 8 and 19, Litwin, Jr. et al. and Schobinger et al. teaches all of the subject matter of the claimed invention with the exception of selectively allocating the timing frame includes determining an optimal size for at least one of the first and second portions based on at least one of upstream and downstream bandwidth utilization data. Balhut from the same field of endeavor teaches efficient bandwidth allocation is achieved by using variable length burst for upstream transmission. Rather than setting the length of each upstream burst at a fixed length, the length of each bust is determined in accordance with the actual bandwidth requirements of the transmitting end user terminal (see column 2 lines 41 – 46). Therefore, it would have been obvious to one of ordinary skill in the art at the time of the invention was made to determine an optimal size as taught by Balhut into the PLC systems as taught by Litwin, Jr. et al. and Schobinger et al. The motivation for doing this is to have an efficient transmission system.

Conclusion

9. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure. Rickard et al. (US 5,977,650), Brown (US 6,144,292), Sutterlin et al. (US 6,414,968 B1), Propp et al. (US 2004/0075535 A1), and Lockridge et al (US 200/0090994 B1) are cited to show a method and system for timing controlled signal transmission in a point to multipoint power line commotions system.

10. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Gary Mui whose telephone number is (571) 270-1420. The examiner can normally be reached on Mon. - Thurs. 9 - 3 EST.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Ricky Ngo can be reached on (571) 272-3139. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

GM 04.11.2007

RICKY Q. NGO
SUPERVISORY PATENT EXAMINER

ATTY DOCKET NO.	APPLICATION NO.
103880-036US	10/671,126
APPLICANT(S)	
Logvinov et al.	
FILING DATE	GROUP ART UNIT
9-25-03	2616 ~~2661~~

INFORMATION DISCLOSURE CITATION

(Use several sheets if necessary)

U.S. PATENT DOCUMENTS

*EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE
/GM/		6,559,757	5/6/03	Deller et al.	340	310.01	
/GM/		6,300,881	10/9/01	Yee et al.	340	870.02	
/GM/		6,275,144	8/14/01	Rumbaugh	340	310.01	
/GM/		6,246,325	6/12/01	Chittipeddi	340	540	
/GM/		5,404,127	4/4/95	Lee et al.	340	310.02	

U.S. PATENT APPLICATION PUBLICATIONS

*EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES	TRANSLATION NO

OTHER DOCUMENTS *(Including Author, Title, Date, Pertinent Pages, Etc.)*

EXAMINER	/Gary Mui/	DATE CONSIDERED	04/11/2007

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

INFORMATION DISCLOSURE CITATION *(Use several sheets if necessary)*	ATTY DOCKET NO. 103880-036US	APPLICATION NO. 10/671,126
	Logvinov et al.	
	FILING 9-25-03	GROUP ART ~~2661~~ 2616

U.S. PATENT DOCUMENTS

*EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE
/GM/		5,355,114	10/11/094	Sutterlin et al.	340	310 A	
/GM/		4,815,106	3/21/89	Propp et al.	375	36	
/GM/		4,642,607	2/10/87	Strom et al.	340	310 A	
/GM/		4,429,299	1/31/84	Kabat et al.	340	310 A	

U.S. PATENT APPLICATION PUBLICATIONS

*EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES	TRANSLATION NO

OTHER DOCUMENTS *(Including Author, Title, Date, Pertinent Pages, Etc.)*

EXAMINER /Gary Mui/	DATE CONSIDERED 04/11/2007

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

Notice of References Cited	Application/Control No. 10/671,126	Applicant(s)/Patent Under Reexamination LOGVINOV ET AL.	
	Examiner Gary Mui	Art Unit 2616	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-6,834,091	12-2004	Litwin et al.	375/356
*	B	US-6,778,550	08-2004	Blahut, Donald Edgar	370/443
*	C	US-5,977,650	11-1999	Rickard et al.	307/3
*	D	US-6,144,292	11-2000	Brown, Paul A.	455/402
*	E	US-6,414,968	07-2002	Sutterlin et al.	370/480
*	F	US-2004/0075535	04-2004	Propp et al.	340/310.01
*	G	US-2004/0090994	05-2004	Lockridge et al.	370/509
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	Schobinger, M.; Meier, S.R.; "A low-cost point-to-multi-point access system based on OFDM transmission" ; IEEE International Symposium on Circuits and Systems, 2002. ISCAS 2002.;□□Volume 5, 26-29 May 2002 Page(s):V-417 - V-420 vol.5
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

A LOW-COST POINT-TO-MULTI-POINT ACCESS SYSTEM BASED ON OFDM TRANSMISSION

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ABSTRACT

A demonstrator for a cost-sensitive access system, with point-to-multi-point-transmission based on OFDM transmission in a shared medium is described. Time-domain-duplex (TDD), time-division multiple access (TDMA) and an efficient and robust synchronization algorithm have been implemented. The basic concepts are usable in radio-links as well as in power-line communication systems.

1. INTRODUCTION

Following the deregulation of the telecommunication markets, network operating companies owning different types of resources are competing about market-shares. Companies owning no twisted-pair copper lines or fibers, are trying to penetrate the access markets using alternative media like radio channels or transmission over power lines. However, transmission characteristics in such channels can be severely distorted (see Fig. 1) and additionally transmission might be exposed to temporal interference (e. g. if bandwidth is shared with other types of users). An access system suitable for distorted channels has to take these channel imperfections into account for the design of the physical layers as well as the MAC-layer.

The competition about market-shares requires cost-efficient solutions, that avoid any overhead, which is not absolutely necessary in an access system. Direct communication between all nodes is considered not necessary and communication is restrained to be possible only between a master (base-station) and slaves (terminals) in order to simplify and cheapen the implementation of the access system. Moreover, random access (e.g. carrier-sense-multiple-access with collision-detect CSMA/CD known from LANs) for the slaves is not supported due to unjustifiable expenses in access-systems. Finally the developed access system is much simpler than DMT-based ADSL.

2. SYSTEM REQUIREMENTS

2.1. Physical Layer (PHY)

The design approach for the physical layer of the demonstrator was based on channel characteristics that contain

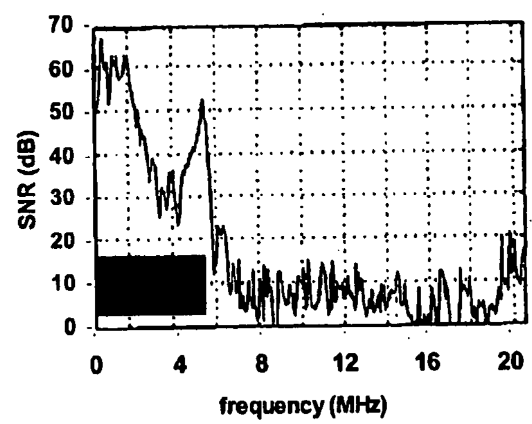

Fig. 1 Available SNR over frequency range for a typical power-line channel

inter-symbol interference (ISI), additive white Gaussian noise (AWGN) and a frequency depending attenuation. In figure 1 the available signal-to-noise ratio of a measured power-line channel is plotted over the frequency, showing that a data transmission is possible in the range between 1 MHz and 5 MHz in this channel. The filled box marks a frequency range where a SNR of more than 11 dB is available to allow a QPSK-based data-transmission.

It has already been motivated [1] that in such situations OFDM has some advantages over a single carrier transmission scheme with respect to cost especially when PSK is sufficient and differential encoding is possible (no equalization, no adaptation required, simple timing recovery described below). The increased symbol-duration in

OFDM transmission reduces the achievable data rates for each sub-carrier, and a parallel transmission in a larger number of frequency division sub-channels has to be used [2,3]. With orthogonal sub-carriers the required signal processing in transmitter and receiver can be realized with a discrete Fourier transform (IDFT/DFT). In OFDM (Orthogonal Frequency Division Multiplex) based transmission systems the input data stream is serial-to-parallel converted in order to modulate these N narrow-band carriers in parallel. In a frequency selective fading environment, the number of sub-channels N is chosen in such a way that the fading process in each sub-channel can be considered as a flat fading process, i.e. not frequency-selective. In order to relax the filter requirements for up-conversion required prior to modulation onto the transmission frequency usually not all N carriers are used. The resulting block of N samples in the time domain is extended with a cyclic prefix (also denoted as guard interval) of the length of the maximum channel impulse response. Due to the low symbol-rate for each sub-channel, the guard interval typically does not waste more than ten percent of the bandwidth. Additionally a forward error correction (FEC) is necessary to correct errors that are caused by loosing information in sub-channels with a very deep notch or caused by other interference.

2.2. Medium Access Layer (MAC)

Point-to-multi-point transmission over shared media requires a carefully designed MAC-layer to avoid performance losses due to collisions as well as an unacceptable overhead for administration. Controlling the communication flow by one master allows an efficient strategy of allocating the available transmission bandwidth to the corresponding slaves and avoids problems caused through hidden-node situations, that can occur not only in radio connections, but in principal in every shared-medium system with channel imperfections.

Especially in conjunction with complex signal processing the classical ALOHA-based protocols such as CSMA/CD are more critical than in the classical LAN standards with binary base-band transmission due to the unavoidable latencies e. g. for block processing. The typical disadvantage of master-slave-systems, that no direct communication between slaves is possible and thereby no ad-hoc networking can be set up between some slaves only, was considered acceptable. An other disadvantage compared to ALOHA-based protocols is the increased delay due to first signaling a transmission request to the master, and then waiting until the request is granted and transmission is scheduled. Due to the limited transmission-bandwidth available and the robustness of this procedure these delays were accepted.

The requirements for the development of the demonstrator-system were:

- communication between master and slaves only, no direct slave-to-slave communication,
- asymmetric data-rate between up-link and down-link should be possible,
- various data-rates for different slaves should be possible,
- robustness against channel-imperfections,
- options to use reduced data-rates communicating with slaves having a very bad channel.

The conceptual design of the MAC-Layer had to reflect the basic properties inherent in the concept for the PHY-Layer based on OFDM transmission:

- Any frame structure has to be composed out of multiples of slots, that are given by the duration of OFDM-blocks.
- Due to the frequency-depending attenuation (band-limited channel) in most of the channels and due to the requirement of asymmetric data rate between up- and down-links, a frequency-division duplex-scheme (FDD) should not be used. Instead a time-division duplex-scheme (TDD) is implemented, so that the MAC-layer handles the allocation of up- and down-link- data onto appropriate time-slots. With TDD the complexity and requirements for filtering in analog and digital domain are relaxed and can be traded against the net data rate e. g. via the number of unused sub-carrier.
- The FEC has to handle blocks that can be any multiple of the length of one OFDM-block, which led to the implementation with a Reed-Solomon code with coded blocks having the same size as the OFDM-blocks, thus providing FEC-information for each OFDM-block.
- Any slave has to be synchronized onto the master, before he is allowed to transmit any request.
- For the registration of new slaves one time-slot is open for ALOHA-based messages from slaves. Due to possibly occurring hidden-node problems these messages have to be protected with an acknowledgement process shielded by timeouts.
- Registered slaves are polled in a periodical scheme whether they have a transmission request and to scan their status. This requires one slot taking the time of one OFDM-block, as different slaves can't share one OFDM-block.
- Granting upstream-transmissions for several slaves can be done in one slot transmitting slave addresses and corresponding upstream-slot numbers.
- The MAC protocol has to take care about the latencies of the physical layer based on the block processing for the OFDM and the block-processing in the Reed-Solomon decoder, which leads to a minimum delay in the receive path of four times the OFDM-symbol duration.

3. SYNCHRONIZATION MECHANISMS

The frequency deviation between transmitter and receiver results in a frequency-offset causing inter-sub-carrier perturbations and a timing-offset, which has to be compen-

sated in order to reach the correct point in time for removal of the guard interval.

3.1 Requirements

Following a reset of the slave the synchronization and the adjustment of the automatic gain control (AGC) are initiated. Correspondingly a detected loss of synchronization (SYNC-LOST) should cause a new synchronization attempt. Due to the TDD/TDMA structure each slave might receive slots originating from the master as well as from other slaves, so that the AGC should be adjusted onto slots from the master after being synchronized to the master. Synchronization without a locked AGC requires a very robust synchronization procedure.

The frame structure used in the system contains one synchronization (SYNC) block in every N slots. The SYNC block is an OFDM-block with arbitrary but known sequence. This SYNC block includes a guard interval like any other OFDM-block. The SYNC block is followed by N-1 OFDM-blocks containing the up-link- and down-link-data controlled by the master.

3.2 Frequency offset

For a frequency offset falling into the order of 1-2% of the sub-carrier spacing inter-sub-carrier perturbations can be ignored. Therefore, given an oscillator tolerance the transmission frequency is upper bounded. Typical radio front-ends in the GHz-range necessitate a carrier-frequency offset-compensation in the time-domain before retransforming with the FFT. A differential encoding (in the frequency domain) does not help to solve the carrier offset problem as long as inter-sub-carrier perturbations occur (which have to be corrected in the time domain).

For wire-line transmission systems low transmission frequencies are appropriate, for example in an application like power-line communication a center-frequency of 2.5 MHz [1] can be chosen. Designing the demonstrator crystal oscillators were used, with maximum tolerances of 40 ppm between the oscillator frequencies in transmitter and receiver, resulting in an offset of 100 Hz, being much less than the sub-carrier spacing of 5 kHz.

3.3 Timing offset

Oscillator tolerances between master and slaves are additionally resulting in a continuously accumulating timing offset, which causes the guard-interval to be removed at a wrong point in time. In order to keep the synchronization simple the required correction after one frame should be on the average not longer than T_{symbol}. This can be implemented by adding or suppressing one sample in the guard interval.

With a carrier-spacing of 5 kHz, resulting in a block-duration of 213 μs including guard-interval and a SYNC-block available after N-1=49 blocks with data, the maximum timing offset between two SYNC-blocks is 0.43 μs based on 40 ppm deviation of the oscillators. This timing offset is smaller than T_{symbol}=0.8μs for a symbol rate of 1.25 MBaud chosen in [1]. N=50 results in an overhead of only 2%. Imperfections in the synchronization lead to an incorrect positioning of the removed interval that is assumed as the guard-interval. A deviation in the direction,

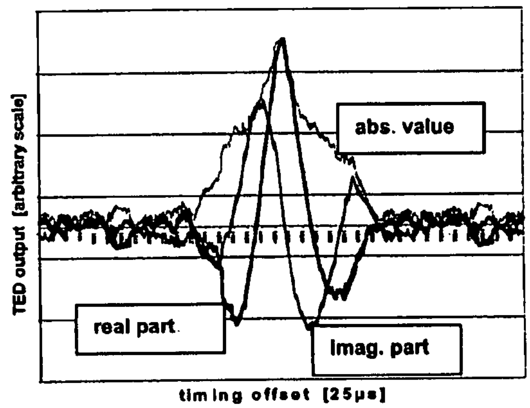

Fig. 2 Output of timing error detector

that the removing of the guard interval starts some samples earlier than optimal shortens the length of possible ISI that is falling into the guard-interval; a deviation in the other direction (starting a few samples later) generates inter-symbol-interference between the current and the subsequent OFDM-block. Hence a small offset of one or two samples in the direction of starting the guard-interval removal earlier should be applied.

3.4 Synchronization

In the frequency domain a timing offset corresponds to phase offsets of the symbols depending on the sub-carrier frequencies. The product of a symbol and the complex conjugate of the symbol of an adjacent sub-carrier is a function of the difference of the corresponding phase offsets. Therefore, for a known SYNC block a timing error detector (TED) can be realized by means of correlation of such products with the corresponding products for perfect timing over an OFDM block. Fig. 2 shows the TED output for timing offsets between ± 2 times the duration of an OFDM block. It is apparent that a S-curve can be obtained from the imaginary part of the TED output with a broad range where locking can be achieved. The S-curve is monotonous in a range between +/- 1/8 of the duration of an OFDM-block and exhibits a pronounced slope in the linear

region between ± 10 T_{symbol} around zero timing offset resulting in good tracking performance under regular operation. Due to the differential coding and the evaluation over a complete OFDM block the S-curve turns out to be very insensitive with respect to channel distortions and noise. For the demonstrator it is important that the TED implementation on the DSP practically does not increase the number of cycles for one OFDM block [1].

In the acquisition mode after RESET or SYNC-LOST a first estimate of the timing offset is needed so that locking becomes possible. In Fig. 2 the absolute value and the real part of the TED output are plotted indicating that especially the latter is well suited to determine a rough estimate of the temporal location of the SYNC block. The maximum value of the real part of the TED output for N=50 subsequent blocks corresponding to a frame indicates the OFDM block that is closest to the temporal position of the SYNC block. If this procedure is repeated 3 times each with a shift by the time corresponding to ¼ OFDM-block it is guaranteed that the overall maximum falls into the range of the S-curve where locking is possible. Note that the time for such a procedure (equivalent to the time for about 201 OFDM-blocks) is acceptable since permanent links are established until the connection is terminated or an unlikely SYNC-LOST has occurred in contrast to synchronization approaches used e. g. in WLAN according to Hiperlan/2 or IEEE 802.11a.

After the acquisition of the synchronization the AGC adaptation is started. Measurements showed that this synchronization is very robust and especially the initial synchronization without an adapted AGC was insensitive to gain variations in the range of 50 dB.

4. REALIZATION OF DEMONSTRATOR

The realized demonstrator is shown in Fig. 3. The partitioning has already been motivated elsewhere [1]. The analog front end (AFE) contains A/D- and D/A- converter using a sampling clock of 10 MHz, low-pass filtering, some amplifiers and the receive-/transmit-switching. This partitioning allows the use of various external up-/down-converters to experiment with diverse types of channels. The DSP board comprises only two Texas Instruments TMS320C6201 DSPs (one for transmitting and one for receiving) which have turned out to be sufficient to perform the complete OFDM signal processing comprising the most computation-intensive tasks. This approach supports transmitting and receiving a net data rate of 1 Mbit/s employing OFDM signals with QPSK–modulated subcarriers in a 1MHz band at a center frequency of 2.5 MHz providing also the flexibility needed to implement further signal processing functions such as the synchronization.

Additional components are the Reed Solomon ICs (FEC), two FPGAs containing the MAC-layer functionality and the interfacing between DSPs and the FEC, and

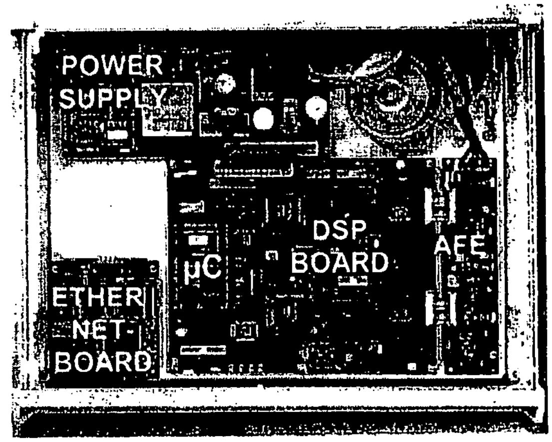

Fig. 3 One of the realized demonstrators

two EPLDs providing the interface between DSP and A/D- and D/A-converter and as well as several control signals between DSP and MAC-layer functionality in the FPGAs especially for timing synchronization purposes. An off-the-shelf ethernet board is used to accomplish the point-to-multi-point communication. A standard µC (SAB80C537) provides the necessary control of all blocks.

5. CONCLUSION

A demonstrator for a point-to-multipoint access system based on OFDM transmission has been described. Targeted to an eventual low-cost solution advantages of possible simplifications on all levels of implementation have been taken. Therefore, the approach may serve as the bottom line for the complexity required for the implementation of such a system.

6. ACKNOWLEDGMENT

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